No. 33.

THE ANATOMY OF THE STEM

OF

DERRIS ULIGINOSA, BENTH.

An Eastern Fish Poison.

BY

PIERRE ÉLIE FÉLIX PERRÉDÈS, B.Sc., F.L.S.

THE WELLCOME CHEMICAL RESEARCH LABORATORIES,
FREDERICK B. POWER, PH.D., *Director*,
6, King Street, Snow Hill,
LONDON, E.C.

Presented to the Scientific Section of the American Pharmaceutical Association, at the Fiftieth Annual Meeting, held at Philadelphia, September, 1902.

THE ANATOMY OF THE STEM OF DERRIS ULIGINOSA, *BENTH.*

An Eastern Fish Poison.

by pierre élie félix perrédès, b.sc., f.l.s.

Introductory.

The study here described was undertaken at the suggestion of Dr. F. B. Power, who at the time was engaged in a chemical investigation of the stems of this species of Derris. The material, comprising the different parts of the plant, was obtained through the kindness of Mr. F. L. Langdale (Retired Lieutenant, Royal Navy), of Wakaya, Fiji, who had brought the drug to the notice of Messrs. Burroughs, Wellcome & Co., of London. In a letter to the latter firm, written in April, 1899, Mr. Langdale drew attention to the poisonous action of the plant upon fish, and stated that it is very abundant in Wakaya, where it is known as "Duva," but in the other islands of the Fiji group it is somewhat scarce on account of having been so largely used by the natives. By means of the specimens supplied, and the vernacular name, the plant was readily identified as *Derris uliginosa*, Benth., by Mr. E. M. Holmes, F. L. S., through whose kindness some further information was also obtained respecting it. Its general botanical characters and distribution are noted in the following work: "*Flora Vitiensis*."—A description of the plants of the Viti or Fiji Islands, with an account of their history, uses and properties. By Berthold Seemann, Ph.D., F.L.S., F.R.G.S. London, L. Reeve & Co., 1865–1873.

The above-mentioned work (p. 65) contains a number of other references to the plant, and a brief abstract of these may be here recorded.

"*Derris uliginosa*, Benth., in Plant. Jungh., vol. i., p. 252; Flor. Austr., vol. ii., p. 272. *Pongamia uliginosa*, D. C. Prodr., vol ii., p. 416. *P. religiosa*, Wight, in Hook. Bot. Misc., vol. iii., p. 301, et in Supp., t. 41, sub nom *P. triphylla*. *Mimosa* e N. Caledonia, Forst. Prodr., et in Sched. Herbarii Mus. Brit. Nomen vern., Vitiense, 'Duva.' A common seaside climber, growing with *Hibiscus tiliaceus* and *Ximenia elliptica*. (Seemann, n. 127; Storck, n. 883; U. S. Expl. Exped.). Also collected in the Tongan Islands (U. S. Expl. Exped.), New Caledonia (Forster), Eromanga (McGillivray), the east coast of New Holland, East Indies, Indian Archipelago, China, and southeast Africa."

"Grows plentifully on the sea-beach, and by its long running root-stock helps to keep the same together. The flowers appear from every part of the plant, and occasionally, as specially noticed by Mr. Storck ('Bonplandia,' vol. x., p. 296), from the roots. The leaves are pounded and thrown into the water by the natives for the purpose of stupefying and then catching fish, the ~~practice~~ being the same as I saw practiced by the American Indians in the Isthmus of Panama and elsewhere."

Derris uliginosa is also described in the "Pharmacographia Indica," vol. i., p. 470. Its habitat is there stated to be the Eastern Himalayas, Western Peninsula, and Ceylon, and its vernacular names—*Pánlata* (Beng.), *Kájarvel*, *Kirtána* (Mar.). It is further stated that "this woody climber is the most widely-spread species of the genus, and is worthy of notice on account of the activity of its bark as a fish poison, for which purpose it is used in Zambesi-land. In India it is known to act as a poison upon worms and the larvæ of insects which trouble the cultivators, whence the Marathi name *Kirtána*, or 'worm-creeper.'"

The following description of the anatomy of the stem of this species of Derris is preceded by a short account of the other portions of the plant, namely, leaves, fruit, and seed. These were examined as received, in the dry state.

Leaves.

Leaves (figs. A and B, plates I and II) compound, imparipinnate, with one or two pairs of lateral leaflets and a terminal one, this terminal leaflet being frequently the largest. Rachis 8 to 12.5 centimeters long, glabrous, channelled on the upper surface, convex on the lower one, compressed at the base into a dark brown, transversely ribbed structure (*rb*, figs. A and B) which is slightly convex on the upper and on the under surface, each side being furnished with two distinct margins, thus presenting a shortly four-winged appearance in transverse section.

Leaflets 6.5 to 9.5 centimeters long, petiolate, oval, with a tendency to an obovate shape, especially in the terminal one, acuminate but obtuse at the apex; somewhat coriaceous; glabrous; yellowish-green on the upper surface, somewhat paler on the under one; petiole 5 to 7 millimeters long, resembling the flattened rachis-base of the leaf in every particular (*p.*, figs. A and B), and tapering into the smooth, wavy, and prominent midrib on the under surface (fig. B); on the upper surface the midrib is depressed (fig. A); the lateral veins, which are scarcely prominent on the upper or on the under surface, are generally given off at a rather wide angle from the midrib, and fork near the wavy and entire margin of the leaflet, forming a somewhat ill-defined and irregularly curved line.

Fruit.

The fruit consists of a somewhat flattened, oblong, or more or less rounded pod (figs. C and D, plate III), generally about 3 centimeters wide and varying in length from 3.5 to 6 centimeters. It bears at the apex the remains of the style (*st.*, figs. C and D) and at the base the scar of the peduncle (*ped. sc.*, figs. C and D). The pericarp consists of three well-defined regions, viz.:

a. An outer papery, glossy, yellowish-grey coat (*a*, figs. C and D)

marked with irregularly arranged raised ridges and dappled with dark brown spots; the prominences (*p.p.*, figs. C and D) due to the ventral sutural wing (*v. s. w.*, fig. C) are especially evident.

β. A middle layer (β, figs. C and D) composed of delicate anastomosing fibrous tissue attached to the woody dorsal ridge (*d. s. r.*, figs. C and D) and ventral sutural wing (*v. s. w.*, fig. C), the latter becoming lost near the base of the pod.

γ. An inner papery layer (γ, figs. C and D) possessing a greyish satiny lustre and bearing the imprints of the fibrous network. The pericarp encloses from one to three seeds, in the pods I have examined; these are attached to the placental surface on the ventral sutural wing.

Seeds.

The seeds (figs. E, F, G and H, plate III) are also somewhat flattened and rounded kidney-shaped in outline. The testa (*test.*, figs. E, F, G and H) is of a rich reddish-brown color, membranous, and very much wrinkled. It invests loosely two somewhat curved, starchy cotyledons (*cot.*, figs. G and H), and, owing to the curvature, a more or less biconvex cavity is formed between these (*sp.*, fig. G). The hilum (*hi.*, figs. E and F) occurs approximately at the middle point of the less curved edge of the seed, while the micropyle (*mic.*, figs., E and F) is situated near one extremity of the hilum, and on opening the seed in the plane separating the two cotyledons the radicle and plumule will be found in this region, as shown in the figure (*rad.* and *pl.*, fig. H).

Stem.

The sample examined, which represents the material employed by Dr. Power for chemical investigation, consisted of pieces varying from 10 to 23 centimeters in length and from 8 to 25 millimeters in diameter.

Most of the pieces occur in groups made up of two portions of stem, twined around each other in the way shown in fig. 1, plate IV.

The surface is rusty-brown, and marked with alternating longitudinal ridges (*l. r.*, fig. 1) and furrows, some of which are very prominent; they follow the twist of the stem, and bear numerous thick-lipped, transverse, reddish-brown warts (*l.*, fig. 1), rendering the bark rough to the feel. The remains of buds (*b.*, fig. 1) are apparent at intervals as protruding masses.

The transverse section of one of the thinner pieces (fig. 2) shows, under a lens, a fairly regular bark (*c.*, fig 2) which is light colored near the periphery, but dark brown, crossed by lighter medullary rays, towards the wood. The wood (*x.*, fig. 2) is yellowish in color, porous, and without any apparent radiate structure, but marked with more or less concentric darker rings (*br. p.*, fig. 2). The portion surrounding the pith

(*c. s.*, fig. 2) is uniformly light yellow in color and compact in structure. The pith (*m.*, fig. 2) is small, light, and friable.

In the larger pieces (figs. 1 and 3) the general structure remains the same, but peripheral strands (*p. b.*, figs. 1 and 3), consisting of a woody core surrounded by bark, have made their appearance; it is to these that the prominent ridges of the stem are due. The light colored peripheral region of the bark has been replaced by a distinct white line (*scl. l.*, fig. 3) separating an outermost dark brown portion (*k.*, fig. 3) from the inner one containing the wavy medullary rays. In the wood the dark bands (*br. p.*, fig. 3) are more distinct. The remaining characters are the same (compare figs. 2 and 3).

ANATOMICAL STRUCTURE.

I. The Bark.

Outer bark (*k.*, figs. 4 and 18, plates V and VI) many cells thick, and consisting of tabular, thin-walled, and tangentially elongated cork cells, arranged in radial rows (figs. 4, 5 and 18).

This gradually passes into the cortex (*cort.*, figs. 4 and 18), which is generally from 10 to 12 cells thick, and composed of large and somewhat irregularly arranged, tangentially elongated, polygonal thin-walled cells; the cortex is terminated by a sclerenchymatous sheath (*scl., l.*, figs. 4 and 18; figs. 6 and 7), made up of thick-walled stone cells (*sc.*, figs. 6 and 7), wedged together so as to form a layer 1 to 3 cells thick, with an occasional gap taken up by a parenchymatous cell (I., fig. 6). At intervals also, groups of (pericyclic?) fibers occur in it (*p. f.* and *p'. f'.*, figs. 4, 6, 7 and 18). This sclerenchymatous sheath invests the bast. Those cortical cells which are in close proximity to the sclerenchymatous sheath frequently consist of sacs containing prismatic crystals of calcium oxalate. The parenchymatous cells abutting internally on this sheath may also contain such crystals, but they are not so abundant as in the previous case.

The bast (figs. 4, 8 and 15) is made up of the bast rays (*B. r.*, figs. 4 and 8), separated by medullary rays (*M. r.*, figs 4 and 8). The medullary rays in the outer portion are wide, and consist of tangentially elongated, polygonal thin-walled cells (figs. 4, 8 and 9); sometimes a single stone cell is found among the latter, sometimes a group of two or three (*sc.*, fig. 4; figs. 10, 11, 12, 13 and 14); these assume a variety of forms, and the thickness of their walls also varies very considerably. In the inner portion the medullary rays narrow down till they become 2 to 4 (or more) cells wide (fig. 4), the component cells becoming radially elongated and tabular in form (figs 4 and 15). The bast rays (*B. r.*, figs. 4 and 8) are wedge-shaped in transverse section, and are traversed by smaller medullary rays for a varying portion of their length (*M. r.*, figs. 4 and 8); the fiber groups of the sclerenchymatous sheath, mentioned above, generally

lie opposite their outer extremities (protophloëm). This, however, is not invariably the case; for instance, in the section from which fig. 4 is sketched, a group (p'. f'., fig. 4) occurs just opposite a medullary ray. The outer extremity of a bast ray consists mostly of collapsed sieve-tubes alternating with bast parenchyma; this arrangement is succeeded by the following for the greater portion of the wedge:

(a) Strands of collapsed sieve-tubes, usually less crushed on the inner than on the outer side (*c. s. t.*, figs. 4, 8 and 15).

(b) Strands of bast fibers (*b. f.*, figs. 4, 8 and 15; fig. 16).

(c) Longitudinal rows of nearly cubical crystal-containing sacs (*cryst.* figs. 8 and 15); these cells always occur in connection with the fibers, and the prismatic crystals of calcium oxalate they contain are enclosed in a thin membrane.

(d) Bast parenchyma, in layers generally two or three cells thick (*b. par.*, figs. 4, 8 and 15); cells approximately isodiametric in transverse section (fig. 8), axially elongated in a longitudinal section (figs. 15 and 17), and marked with pits on the radial walls (fig. 17).

Towards the inner side the sieve-tubes become less collapsed, till their normal shape is reached (*s. t.*, fig. 4). The innermost layer of the bark consists of undifferentiated desmogen cells (*camb.*, fig. 4).

It is to be noted that while the bast fibers do not react appreciably with phloroglucin and hydrochloric acid, the crystal-containing sacs do so very readily. With chlor-zinc-iodine solution the bast fibers (and the fibers of the sheath groups also) are stained purplish-brown; it is evident, therefore, that lignification, if it has taken place here at all, has done so but slightly.

A section through a "wart" shows the typical structure of a lenticel (*l.*, fig. 18).

Cell Contents.—The cells of the corky layer contain dark brown coloring matter (fig. 5), turned black by ferric chloride, but almost unaffected by caustic potash, chloral hydrate or alcohol. The cells of the cortex also contain brown coloring matter, but it is less dense and not nearly so intractable as that of the cork; it is darkened by ferric chloride; starch may also occur here. The cells of the medullary rays may contain starch, in simple grains throughout (fig. 19); brown coloring matter is also present, but more sparingly; it is dissolved by caustic potash or chloral hydrate and darkened by ferric chloride. The cells of the bast parenchyma are uniformly filled with dense brown coloring matter, darkened by ferric chloride and by caustic potash, and subsequently dissolved by the latter, also soluble in alcohol and chloral hydrate; to this localization of the coloring matter the dark wavy appearance of the inner portion of the bark is due. With a strong lens it is possible to make out the alternating tangential lines of dark bast parenchyma and light bast fibres, together with the collapsed sieve-tissue.

The presence of calcium oxalate and its mode of occurrence has already been mentioned.

II. The Wood.

The wood in transverse section shows the following general arrangement:

Medullary sheath (*m. s.*, fig. 20, plate VII) very distinct, and surrounded by a compact sheath of strongly lignified tissue (*c. s.*, fig, 20), traversed radially by strands of vascular tissue (*vb.*, fig. 20) and by medullary rays; the latter are not easily distinguishable from the ordinary tissue of the sheath in transverse section; their component cells, however, are somewhat larger, and occur in more regular radial rows; they are, furthermore, distinguished by abundance of starch.

The remainder of the wood (that is, the bulk of the wood-cylinder) is composed of wood vessels (*v.*, and *gp. v.*, figs. 20 and 21), surrounded by thick-walled and lignified parenchymatous cells (*x. par.*, figs. 20 and 21), and of groups of wood-fibers (*w. f.*, figs. 20 and 21), either of these alternating more or less regularly with thin-walled parenchyma (*t. w. p.*, figs. 20 and 21). The whole is traversed by medullary rays (*m. r.*, figs. 20 and 21) which are usually two or three cells wide, and which follow a tortuous course, owing to the great size of some of the vessels.

The details of these various tissues and cell-forms, which will now be described, are shown in the accompanying figures.

(a) The vessels. Some of these are very large, and occupy, together with the accompanying parenchymatous cells, the whole space between two contiguous medullary rays (*v.*, figs. 20 and 21); others are much smaller, and usually occur in groups (*gp. v.*, figs. 20 and 21). The large vessels are generally of the usual type (*v.*, figs. 22 and 24; fig. 23); some, however, may be found which resemble tracheïds in form (fig. 25), the perforations occurring on oblique or lateral walls (*perf.*, fig. 25); in the small vessels the perforations are nearly always obliquely placed (*perf.*, figs. 26, 27 and 28), in every case the walls are furnished with transversely elongated, and, in most cases, evidently bordered pits (figs. 24 to 28). Some of the vessels contain yellowish-brown columnar masses (shown in longitudinal section in fig. 23, in transverse section in fig. 29); these masses stain very readily with phloroglucin and hydrochloric acid, but are unaffected by ferric chloride, chlor-zinc-iodine, sulphuric acid, sulphuric acid and iodine, chloral hydrate or alcohol; they are rendered slightly more hyaline by caustic potash, and resist the action of Schultze's maceration mixture to a remarkable degree.

(b) The wood-fibers (*w. f.*, figs. 20, 21, 22 and 24) occur either in separate groups, as above stated, or in connection with the lignified parenchyma surrounding the vessels (fig. 21). In the former case they have, closely associated with them, strands of crystal-containing sacs (*cryst.*, figs. 21, 22 and 24) which are arranged in axial rows (*cryst.*, figs.

22 and 24); the crystals are similar to those of the bast, but larger as a rule, and, like the latter, are enveloped in a thin membrane. As in the bast, these sacs, or rather the crystal-enveloping membranes in them, react strongly with phloroglucin and hydrochloric acid. The fibers are polygonal in transverse section, and have a small lumen, the middle lamella is strongly lignified and contrasts sharply with the central portion when treated with staining reagents (*w. f.*, fig. 21); for instance, with phloroglucin and hydrochloric acid the former reacts strongly, whereas the latter is hardly affected; with chlor-zinc-iodine the latter is stained dark purplish-brown, while the former is stained yellow, giving an appearance which is thus roughly the converse of that produced by the first named reagent. In longitudinal section the fibers are seen to possess simple pointed ends (*w. f.*, figs. 22 and 24).

(c) The elements constituting the bulk of the compact sheath surrounding the pith are fibrous in form (figs. 30 and 31); they are furnished with simple and somewhat distant pits on their walls, and are chambered by delicate transverse septa. Except at the boundaries of the sheath it is very difficult indeed to determine their exact shape; this may be accounted for by the fact that their ends are variously forked and elongated (as shown in figs. 32 to 36, which represent these elements isolated by maceration) and would, therefore, be intimately interlocked in the tissue.

(d) The general parenchyma. In the neighborhood of the vessels this consists of cells with strongly lignified walls (*x. par.*, figs. 20, 21, 22 and 24); in transverse section these cells are polygonal in form (*x. par.*, figs. 20 and 21; figs. 37 and 40) and marked with large, and for the most part, simple pits (fig. 37); in longitudinal section (*x. par.*, figs. 22 and 24; figs. 38 and 39) they are usually tabular in form, elongated in axial direction, and furnished with round or oval pits on their radial (fig. 38) and tangential (fig. 39) walls, these pits having not infrequently the appearance of being bordered. They contain an abundance of starch in simple grains (fig. 40).

The remaining cells of the parenchyma (*t. w. p.*, figs. 20, 21, 22, 24 and 41) are thin-walled and more nearly isodiametric in transverse section than the above (*t. w. p.*, fig. 21; fig. 41), while in longitudinal sections they are almost identical in form with them (*t. w. p.*, figs. 22 and 24); they contain dense brown coloring matter (fig. 41), similar to that of the bast parenchyma in every particular.

It is to the preceding tissue that the darker rings (*br. p.*, figs. 2 and 3), seen under a lens, are due.

(e) The cells of the medullary rays are generally tabular in form and radially elongated in transverse and in radial longitudinal sections (figs. 20, 21, 22, 42 and 43), polygonal and isodiametric in tangential

longitudinal section (figs. 24 and 44). In the compact sheath investing the pith, however, they are isodiametric in transverse (fig. 20), but axially elongated in longitudinal section (fig. 45).

In the vicinity of the vessels these cells have, like those of the general parenchyma, strongly thickened and lignified walls (*l. m. r.*, figs. 21, 22, 24; figs. 42, 43 and 44) which are furnished with more or less rounded pits, most numerous on the tangential walls (fig. 44), and not infrequently also presenting a bordered appearance (figs. 42, 43 and 44).

The portions of the medullary rays which traverse the pith-investing sheath are entirely composed of lignified cells which resemble those just described in most points, but they are axially and not radially elongated (fig. 45), as already noted.

The other cells of the medullary rays (figs. 20 and 21) differ from the first of the above in being thin-walled, not lignified, and in possessing obviously simple pits only.

All the cells of the medullary rays contain an abundance of starch in simple grains, similar to those shown in fig. 40.

III. The Pith.

The pith consists of thin-walled tissue (*m.*, fig. 20; fig. 46) in which numerous stone-cells occur (*sc.*, figs. 20 and 46); in both cases the cells are more or less isodiametric in all directions, rounded in form, and separated by intercellular spaces (*int. c. sp.*, figs. 20 and 46). The walls of the stone-cells are lignified and canaliculate, but comparatively slender; in surface view the canals are evident as simple pits.

All the cells of the pith may contain starch. In the vicinity of the medullary sheath an occasional stone-cell is found which is axially elongated and contains brown coloring matter, similar to that of the cork cells in the bark.

IV. The Peripheral Strands.

A portion of one of these is shown in transverse section in fig. 47. It is found to reproduce, in miniature, the structure of the whole stem in all essential particulars. It will be noticed that there are two sclerenchymatous layers present, one external and continuous with that of the normal portion of the bark (*scl. l.*); the other internal, pushed inwards, and separated from the parent layer by a gap (*scl. l.* (2)). It would seem, at first sight, that this internal layer is of subsequent formation; this, however, is rendered improbable by the fact that the pericyclic fibres are found *only* in the internal layer—in no case have I found them in the external one. This tends to show pretty conclusively that these peripheral strands are of cortical origin.

Note.—The term "bark" has been used in its ordinary English signification. For an explanation of this see a previous paper on "The Anatomy

of the Bark of *Robinia Pseud-acacia*, Linné," in the *Year-Book of Pharmacy*, 1901, p. 380.

EXPLANATION OF FIGURES.

Plate I. Fig. A. Leaf, upper surface. *rb.*, flattened, expanded and ribbed rachis-base of leaf; *p.*, petioles of leaflets. Natural size.

Plate II. Fig. B. Leaf, under surface. Lettering as in A. Natural size.

Plate III. Fig. C. A long, and Fig. D. a short pod. *st.*, remains of style; *ped. sc.*, scar of peduncle; α, outer ridged and dappled coat; β, middle fibrous layer; γ, inner satiny coat; *v. s. w.*, ventral sutural wing; *d. s. r.*, dorsal sutural ridge; *pp.*, prominences due to ventral sutural wing. Natural size.

Plate III. Figs. E and F. Seeds, external view. *test.*, testa; *hi.*, hilum; *mic.*, micropyle. Natural size.

Plate III. Fig. G. Transverse section of seed. *test.*, testa; *cot.*, cotyledons; *sp.*, space enclosed by cotyledons. Natural size.

Plate III. Fig. H. Seed, showing cotyledons separated. *test.*, testa; *cot.*, cotyledons; *pl.*, plumule; *rad.*, radicle. Natural size.

Plate IV. Fig. I. Portions of two stems, showing twining habit. *b.*, remains of buds; *l. r.*, longitudinal ridges; *l.*, reddish-brown warts; *c.*, bark; *x.*, porous wood; *p. b.*, peripheral strands; *w.*, place where bark has been wounded. Natural size.

Plate IV. Fig. 2. Transverse section of a small piece. *c.*, bark; *x.*, porous wood; *c. s.*, compact sheath surrounding pith; *m.*, pith; *br. p.*, irregnlar dark streaks. × 3 diameters.

Plate IV. Fig. 3. Transverse section of an average-sized piece (*e. g.*, Fig. 1). *k.*, outer dark brown layer; *scl. l.*, sclerenchymatous layer; *p. b.*, peripheral strands. Other lettering as in Fig. 2. × 3 diameters.

Plate V. Fig. 4. Transverse scection through bark. *k.*, cork; *cort.*, cortex; *scl. l.*, sclerenchymatous sheath; *p. f.* and *p' f'.*, fiber groups; *M. r.*, medullary rays; *m. r.*, smaller medullary rays; *B. r.*, bast rays; *sc.*, stone cells; *c. s. t.*, collapsed sieve-tissue; *b. f.*, bast fibers; *b. par.*, bast parenchyma; *s. t.*, sieve-tubes; *camb.*, desmogen cells. × 75 diameters.

Plate V. Fig. 5. Cells of cork-layer in transverse section. × 150 diameters.

Plate V. Fig. 6. Portion of sclerenchymatous sheath in transverse section. *sc.*, stone cells; *p. f.*, group of fibers; *I.*, thin-walled parenchymatous cell; *cort.*, cortical region. × 150 diameters.

Plate VI. Fig. 7. The same in radial longitudinal section. Lettering as in Fig. 6. × 150 diameters.

Plate VI. Fig. 8. Portion of bast in transverse section. *cryst.*, crystal-bearing cells. Other lettering as in Fig. 4. × 150 diameters.

Plate VI. Fig. 9. Cells from wide portion of medullary ray in radial longitudinal section. × 180 diameters.

Plate VI. Figs. 10 and 11. Stone cells of medullary ray in transverse section. × 150 diameters.

Plate VI. Figs. 12, 13 and 14. Stone cells of medullary ray in radial longitudinal section. × 150 diameters.

Plate VI. Fig. 15. Portion of bast in radial longitudinal section. Lettering as in Fig. 8. × 150 diameters.

Plate VI. Fig. 16. Fragment of a bast fiber. × 150 diameters.

Plate VI. Fig. 17. Cell of bast parenchyma showing pits on radial walls. × 180 diameters. The cross in Fig. 15 indicates the region in which the cell occurred.

Plate VI. Fig. 18. Transverse section through a "wart." *l.*, lenticel. Other lettering as in Fig. 4. × 75 diameters.

Plate VI. Fig. 19. Cell of medullary ray in transverse section, showing simple starch grains. × 180 diameters. The cross in Fig. 8 indicates the region in which the cell occurred.

Plate VII. Fig. 20. Transverse section through pith and central portion of wood. *m.*, pith; *m. s.*, medullary sheath; *c. s.*, compact sheath; *x.*, wood; *v.*, vessels; *gp. v.*, groups of vessels; *px.*, protoxylem groups; *v. b.*, vascular strand transversing compact sheath; *m. r.*, medullary rays; *t. w. p.*, thin-walled parenchyma; *w. f.*, wood fibers; *x. par.*, lignified parenchyma; *sc.*, stone cells of pith; *int. c. sp.*, intercellular spaces in pith. × 75 diameters.

Plate VII. Fig. 21. Transverse section through wood about half way between cambium and pith. *l. m. r.*, lignified portion of medullary ray; *cryst.*, crystal-containing cells. Other lettering as in Fig. 20. × 150 diameters.

Plate VIII. Fig. 22. Radial longitudinal section through wood, in same region as Fig. 21. Lettering as in Fig. 21. × 150 diameters.

Plate VII. Fig. 23. Longitudinal section through vessel, showing contents. × 150 diameters.

Plate VIII. Fig. 24. Tangential longitudinal section through wood, in same region as Figs. 21 and 22. Lettering as before. × 150 diameters.

Plate VIII. Figs. 25, 26, 27 and 28. Segments of vessels isolated by maceration. *perf.*, perforations. × 150 diameters.

Plate VIII. Fig. 29. Transverse section through small vessel, showing granular contents. × 300 diameters.

Plate VIII. Fig. 30. Element of compact sheath from the border of the pith, showing transverse septa and pits. × 150 diameters.

Plate VIII. Fig. 31. A group of the same. × 300 diameters.

Plate VIII. Figs. 32, 33, 34, 35 and 36. Ends of elements of compact sheath, showing forking and elongation (isolated by maceration). × 150 diameters.

Plate IX. Fig. 37. Transverse section through cells of wood parenchyma in the neighborhood of a vessel, showing pits. × 300 diameters.

Plate IX. Fig. 38. Radial longitudinal section through same. × 300 diameters.

Plate IX. Fig. 39. Tangential longitudinal section through same. × 300 diameters. (This has been left unshaded in order to show the thickening more clearly.)

Plate IX. Fig. 40. Transverse section through same, showing starch. × 300 diameters.

Plate IX. Fig. 41. Transverse section through thin-walled parenchyma of wood, showing contents. × 300 diameters.

Plate IX. Fig. 42. Transverse section through lignified portion of medullary ray. × 300 diameters.

Plate IX. Fig. 43. Radial longitudinal section through same. × 300 diameters.

Plate IX. Fig. 44. Tangential longitudinal section through same. × 300 diameters.

Plate IX. Fig. 45. Radial longitudinal section through portion of medullary ray of compact sheath. × 300 diameters.

Plate IX. Fig. 46. Longitudinal section through pith. Lettering as in Fig. 20. × 150 diameters.

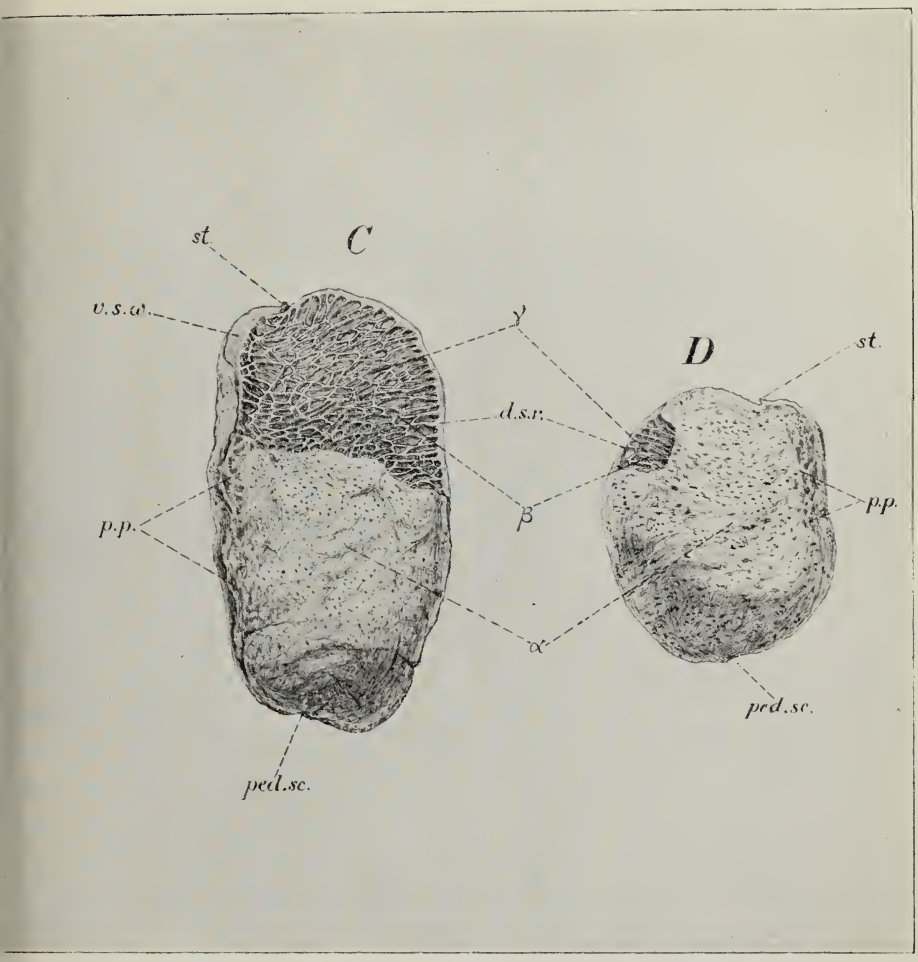
Plate IX. Fig. 47. Transverse section through portion of peripheral strand. *scl. l.*, additional sclerenchymatous layer; *scl. l.* (2) inner sclerenchymatous layer. (This is part of the original sclerenchymatous sheath broken away from the parent one and pushed in during the development of the peripheral strand); *camb.*, cambium. Other lettering as before. × 75 diameters.

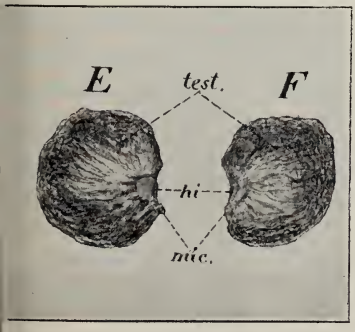
Lignified tissue shaded throughout, as far as practicable.

The Wellcome Research Laboratories, London.


A
p
p
p
rb.


B
p.
p.
p.
p.
p.
rb.


C
st.
v.s.o.
p.p.
ped.sc.
γ
d.s.r.
β
α
D
st.
p.p.
ped.sc.


E
test.
F
hi.
mic.

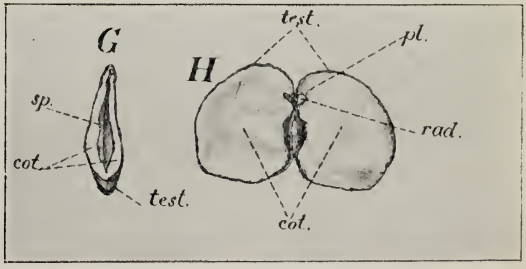
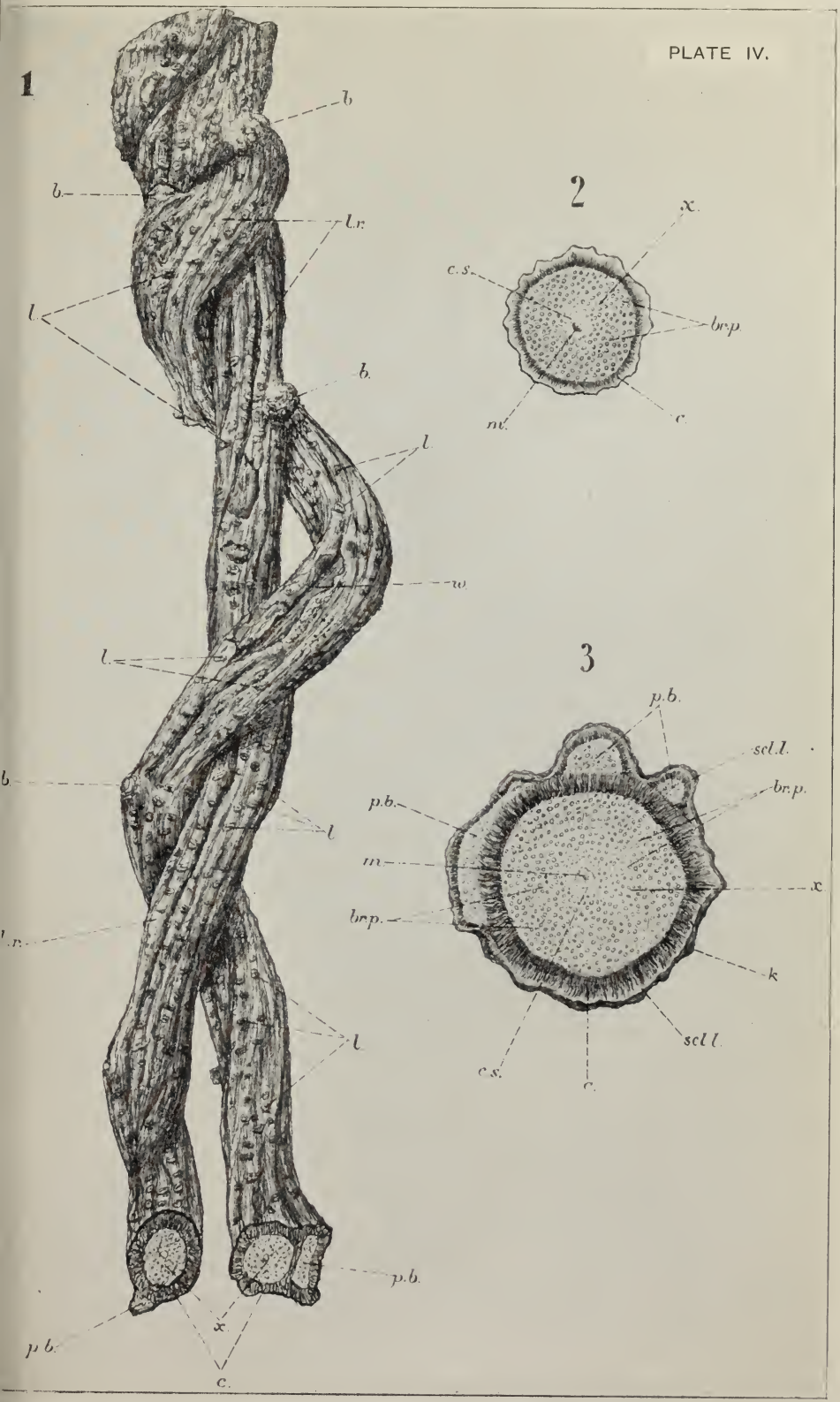
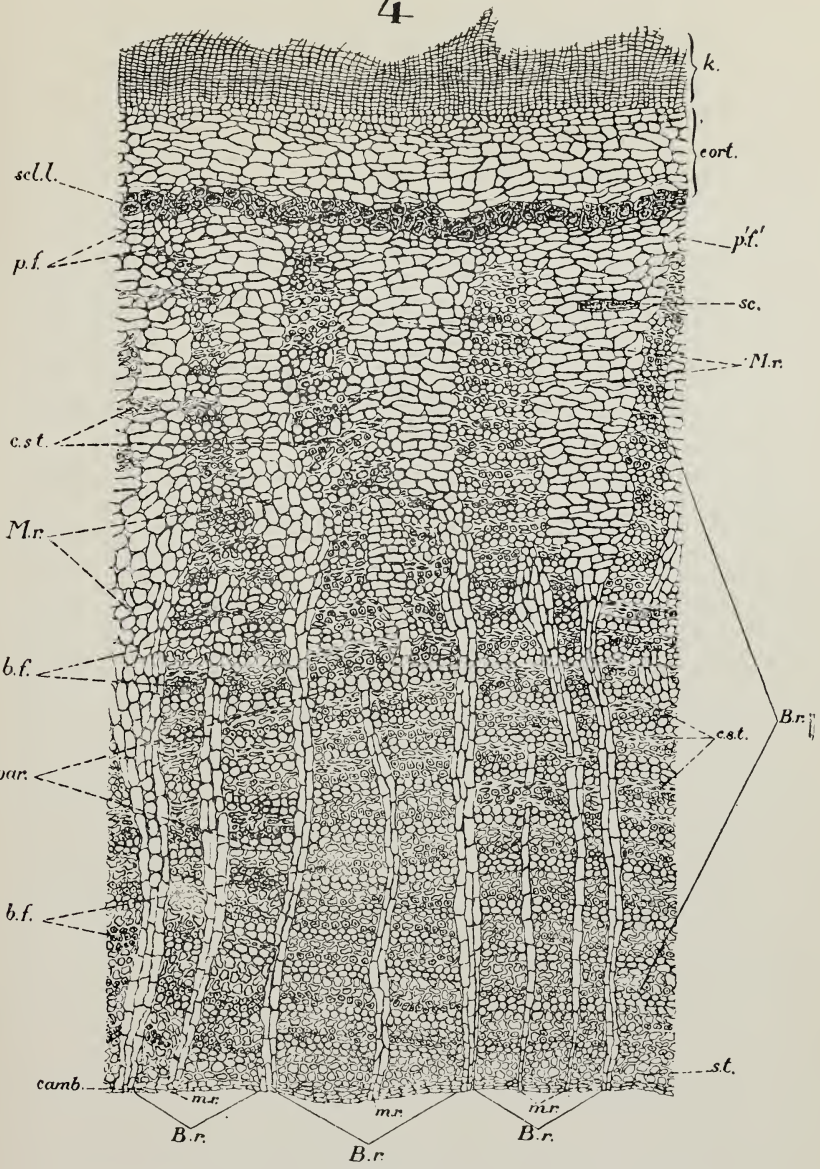

G
sp.
cot.
test.
H
test.
pl.
rad.
cot.

PLATE IV.


1
b
b
l.r.
l
b.
l
w
l.
b
l
l.r.
l
p.b.
x.
p.b.
c.
2
x.
c.s.
br.p.
m.
c.
3
p.b.
scl.l.
br.p.
p.b.
m
x
br.p.
k
scl l.
c.s.
c.

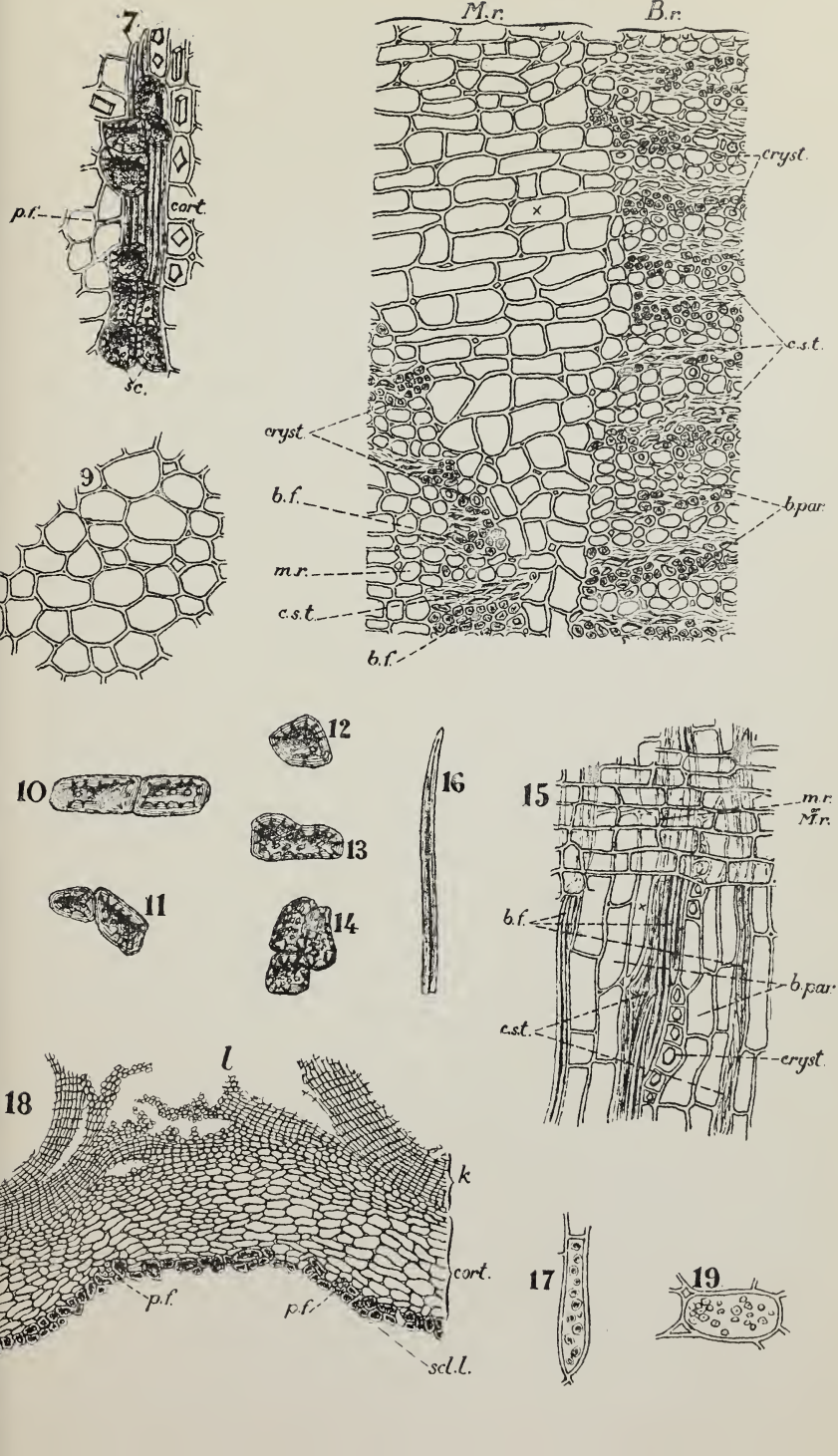
4


k.
cort.
scl.l.
p.f.
p.f.'
sc.
M.r.
c.s.t.
M.r.
b.f.
B.r.
c.s.t.
b.par.
b.f.
s.t.
camb.
m.r.
m.r.
m.r.
B.r.
B.r.
B.r.

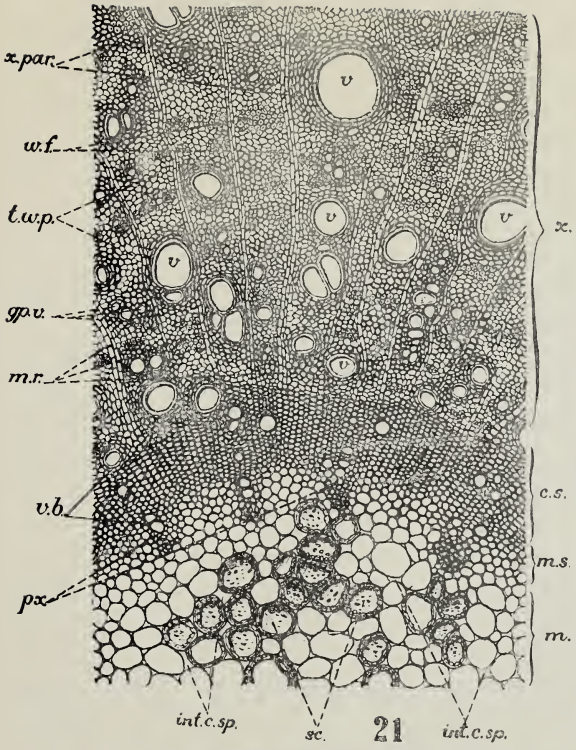
5

6

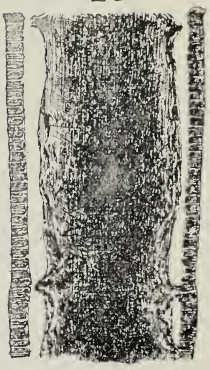

l
cort.
sc.
p.f.


8
M.r.
B.r.
cryst.
c.s.t.
b.par.
cryst.
b.f.
m.r.
c.s.t.
b.f.
7
p.f.
cort.
sc.
9
10
11
12
13
14
16
15
m.r.
M.r.
b.f.
b.par.
c.s.t.
cryst.
18
l
k
cort.
p.f.
p.f.
scl.l.
17
19

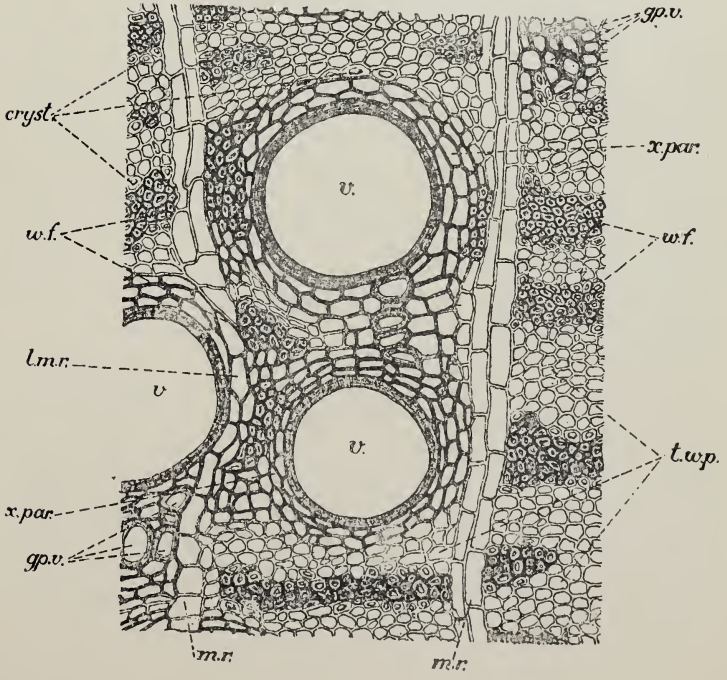
20

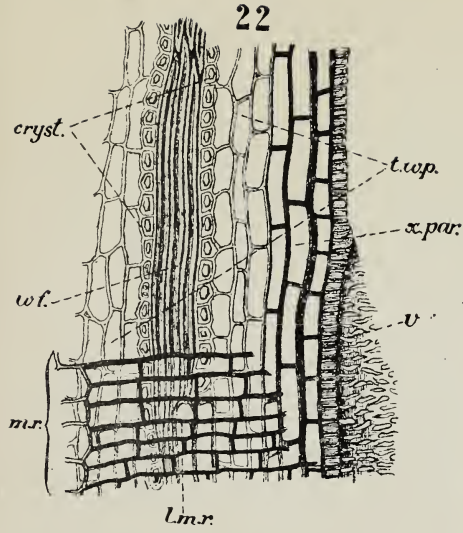

x.par.
w.f.
t.w.p.
gp.v.
m.r.
v.b.
px.
v
x.
c.s.
m.s.
m.
int.c.sp.
sc.
int.c.sp.

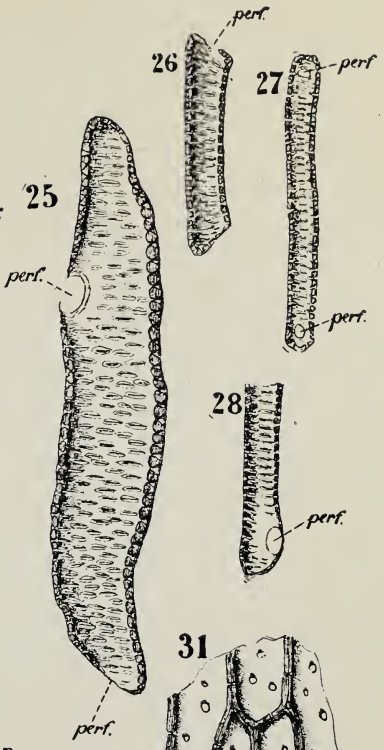
23

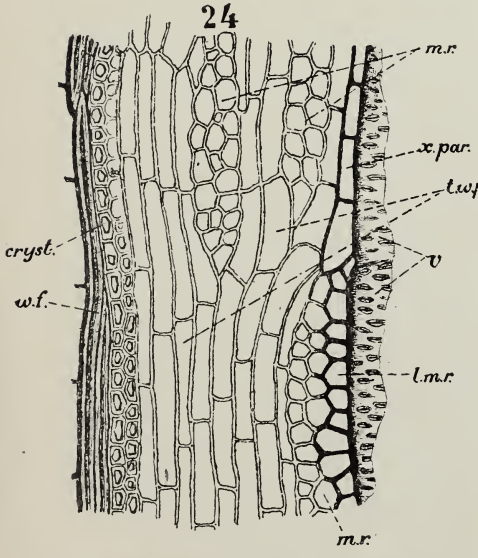


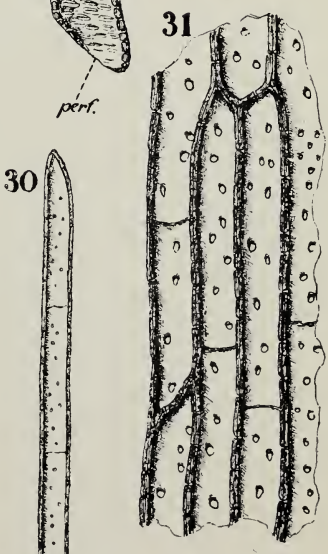
21

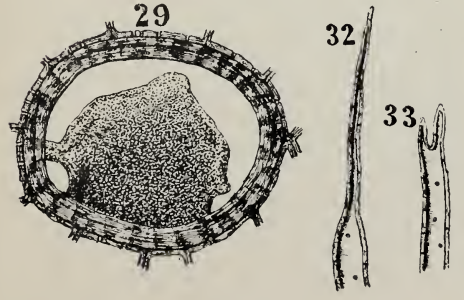

gp.v.
cryst.
x.par.
v.
w.f.
w.f.
l.m.r.
v
v.
t.w.p.
x.par.
gp.v.
m.r.
m.r.

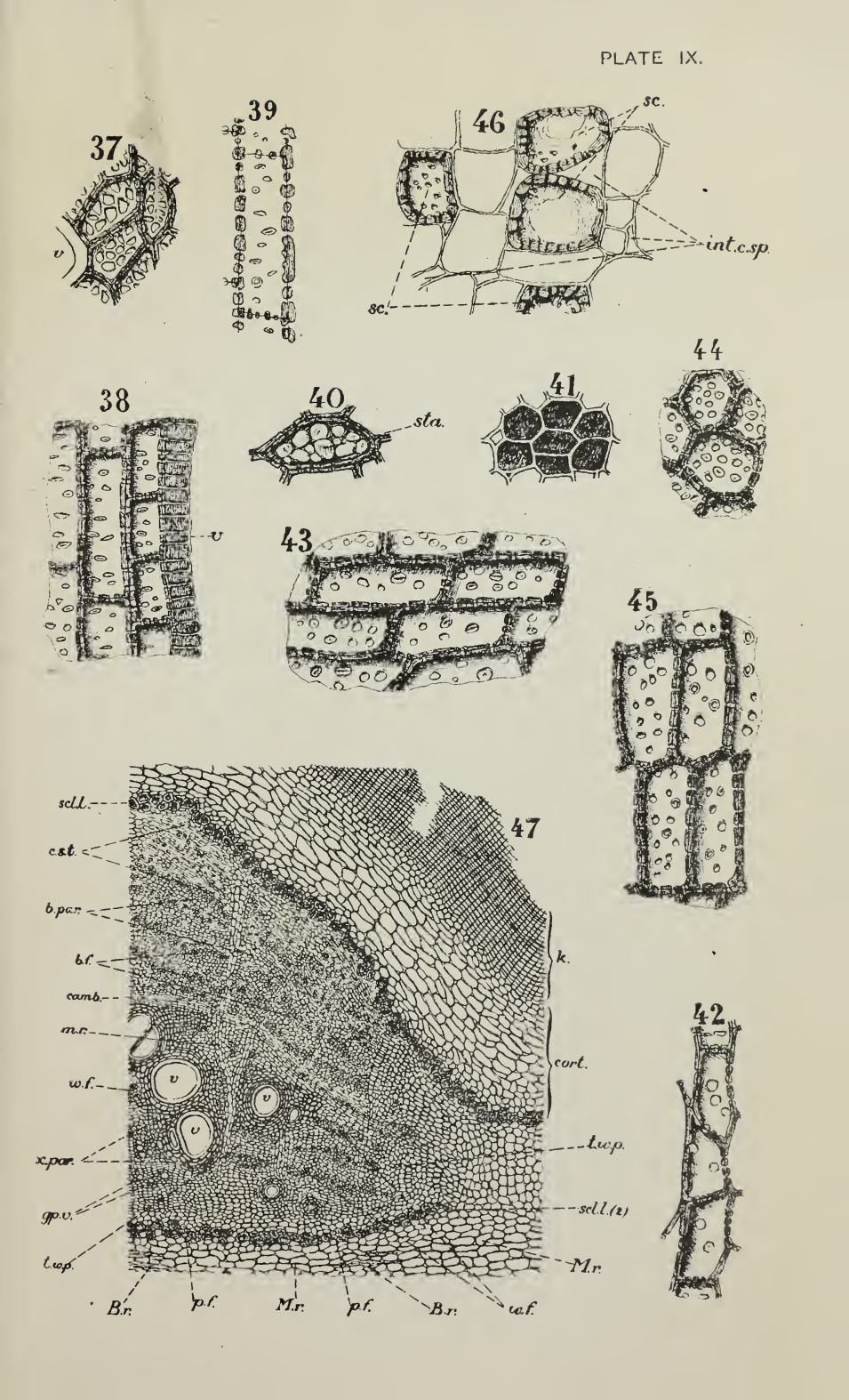

22
cryst.
t.w.p.
x.par.
w.f.
v
m.r.
l.m.r.


perf.
26
27
perf.
perf.
25
perf.
28
perf.
perf.


24
m.r.
x.par.
t.w.p.
cryst.
v
w.f.
l.m.r.
m.r.


31
30


29
32
33
34
36
35


37
v
39
46
sc.
int.c.sp.
sc.
44
38
40
sta.
41
v
43
45
47
scl.l.
c.st.
b.par.
b.f.
camb.
m.r.
w.f.
x.par.
gp.v.
l.wp.
v
v
v
k.
cort.
l.wp.
scl.l.(t)
M.r.
B.r.
p.f.
M.r.
p.f.
B.r.
w.f.
42